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The Extent to which Weeds Modify the Transpiration of Cereals

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SUMMARY

This work on transpiration involved a study of the competition and the comparison of the growth of wheat, of wheat with mustard, of oats alone and oats with mustard. To determine the growth and development taking place in the various cultures, measurements were made at frequent intervals of the increases in leaf area and of the amount of water lost. The data clearly show that weeds require a large amount of water.

Comparing the pure and mixed cultures leaves no doubt but that a weed like mustard impairs the crop. The effect is evidenced in the fact that a culture of wheat and mustard attained its maximum leaf area later than a culture which contained only wheat; cultures of oats and mustard attained maximum leaf area later than cultures of oats alone. The results secured indicate that such a procedure will cut down the dry weight produced.

It is brought out that where oats are grown thick enough, they will offer a competition between themselves. Such growth, however, offers better means for the eradication of weeds like mustard by the process of competition. From the results presented in this work, oats in all probability would be better for this purpose than wheat.

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In the growth history of any economic plant, it is usually an infrequent occurrence for it to have water at the optimum amount. Usually there are times of drouth. Water is a most important item and its conservation should receive the utmost consideration. All plants give off an enormous quantity, practically all in the transpiration stream. This water, released into the air, is later condensed and again made available for absorption thru the root system, conducted to the aerial parts and given off again in the form of water vapor.

Transpiration is affected in a large measure: (1) by the evaporating power of the air, (2) by the supply of water available to the roots, and (3) by certain physical properties of the tissues themselves.

The aerial environment or external conditions (2, 9), including such factors as temperature, humidity, and wind velocity, produce what is designated as the evaporating environment. A modification of any one of these factors will markedly influence transpiration. Cylindrical and spherical atmometers have been successfully used to measure this environmental complex (18, 19). The physics of transpiration has been treated by Renner (29), and Sierp and Noack (31).

The roots are the absorbing organs and the growth and development of tops are dependent upon the root mass. Huber (13) has recently called attention to this fact. No more water can be given off than is taken up. The water supplying power of the soil must then be associated primarily with the moisture and the inorganic constituents present. Muenscher (27) has found that the transpiration rate may be reduced by increasing the concentration of the nutrient solution. His results do not support the proposition that transpiration has an important role in supplying plants with nutrient salts. In a recent publication Hoagland (12) has pointed out that it is a question whether the soil medium is able to furnish the required quota of each element needed in each particular phase of the growth cycle. Even tho it is recognized that absorption is primarily associated with ions, this does not in itself give an explanation for the association with the ions of such an excessive intake of water, or for the maintenance of conduction and a transpiration almost incredible.

A plant responds readily to the moisture environment; especially is this noticeable when a plant has been grown in a soil medium where the moisture content may be regarded as having been below the optimum. Spalding (32) pointed out that a creosote bush (*Covillea tridendata*) grown with a plentiful supply of moisture gave off water 3.7 times as rapidly as one grown under arid conditions. Briggs and Shantz (6), Caldwell (8), and Shive and Livingston (30) have shown that there is on wilting a break in the balance between the water intake and the water outgo. Bakke (1, 2) has demonstrated that the time interval for changing standardized hygrometric paper (cobalt chloride) is considerably increased when no water is added to a growing plant.

It is known that the water given off in the transpiration stream passes off as such from the leaf surface. A small amount permeates thru the cuticle, but by far the greatest amount is emitted from the stomatal aperatures. Darwin (10), Lloyd (24), Knight (17) and Loftfield (25) have sought to determine the exact process in transpiration but their subsantiations are not satisfactory.

The work of Bergerstein (7), Bakke and Livingston (3), and Trelease and Livingston (33) shows that a number of complicated internal factors are involved.

The question of the resistance to the passage of water, or of the force with which water is held in the tissues, has been presented by several investigators (1, 20, 22, 23). There was found to be a difference in the amount of water given off and in the moisture content of leaves at various times of the day (22), and the whole proposition correlates itself with the fact that the plant cells hold on to water contained in them with a greater force at certain times than at other times. As a consequence the maximum transpiration, as well as the greatest foliar transpiring power index, occurs at a time previous to the greatest evaporation.

If we accept Livingston's (21) statement that transpiration is practically a simple function of the leaf surface and that the total transpiration is a measure of the growth of a plant, whether it is one growing in a waste place or one of economic importance, a transpirational history of a plant will at the same time serve as a history of its development.

Kisselback (15), who has carried on extensive experiments in Nebraska, using corn, has found that the transpiration from corn is approximately one-sixth of that taking place from a free water surface having the same area as the corn plant and that the air just above a growing crop offers an evaporating environment much more intense than the medium at the surface. At another time Kisselback and Montgomery (16) pointed out that the

evaporation rate from a free water surface is about one-half as much at the ground as it was 10 feet above ground.

Wherever two or more plants are grown in close proximity there is bound to be a certain amount of competition among them whether considered from the standpoint of the external factors or of internal forces. Montgomery (26) pointed out that certain individual plants are less fit to survive under a particular environment than others;—for instance, where large plump seeds were planted in competition with small or poorly developed seeds there the production of plants was decreased 28 percent while that of the small or shrunken seed was decreased 38 percent. Where two varieties were planted together they usually developed so that the advantage was in favor of one of the varieties, and if continued, one variety would entirely replace the other. Oats, *Gartan* No. 70 (black oats), outyielded *Swedish Select* (white oats) when sown alone, but when sown with the white oats the latter produced the greater crop. Montgomery (26) suggested that the difference may be due to early habits of growth:—the black oats make little growth at first and cling rather close to the ground for several weeks, while the other variety grows rapidly from the start. Both varieties were of the same height at time of maturity.

Weeds are regarded simply as plants out of place. Their physiological processes of absorption, conduction and transpiration are fundamentally the same as for crop plants. One of the ways, according to Pammel (28), in which weeds are injurious is in their use of the moisture necessary for their growth. Hunt (14) also makes the assertion that weeds are harmful because they exhaust the moisture from the soil. Corn plots on which weeds grew contained less moisture than similar areas kept cultivated. Where the weeds were not allowed to start until June 27, there was a much greater yield than where the weeds were permitted to grow after June 14. Kisselback (15) has given the information that weeds, like sunflowers, use more than three times as much water per plant as corn. The water used per unit of dry matter was more than twice that of corn. In other words, one plant consumed as much as a hill of corn. In this connection Gates and Cox (11) have arrived at the conclusion that weeds make the cultivation of corn necessary.

Brenchley (4, 5) found that the May weed (*Anthemis sp.*) is very impatient of competition. If the crop with which it grows is in any way heavy, little or no May weed is to be found, altho this weed may occur in enormous quantities around the edges of fields, along fences or in clearings. The growing crop has little influence on competing weeds except to crowd or smother out species which would otherwise be present. In a subsequent publication the same author points out that a weed like mustard

(*Brassica*) did better when it was associated with a grain crop than when it was subjected to the competition of its own species. The wheat plant is less effective in reducing the growth of the mustard than of some other weeds. *Brassica* present in a wheat field, even in moderate amounts, might do considerable damage.

The present study is an attempt to determine the effect which the weed factor has upon the growth and development of wheat and oats. At the same time that consideration was given to the effect of mustard upon wheat and upon oats, the effect of wheat upon wheat and oats upon oats was taken into account. Considering transpiration as an index of growth, it is recognized that transpiration measured at stated intervals on the basis of unit areas, from the time the seedlings appear until maturity will give comparable results, which are dependable and valuable.

METHODS

The experimental work in the present study was performed in the experimental greenhouses of the Department of Botany from January 1, 1918, to the following June. The economic plants used in the experiments were wheat, (Marquis), *Trituum vulgare,* and oats (Iowa 103), (*Avena sativa*). The weed was the common mustard, *Brassica nigra.* The seed was planted in garden soil, held in galvanized pails 25x20 cm. Each contained 6 kilograms of air dried soil. In all there were 10 cultures: (1) two of wheat, (2) two of oats, (3) one of mustard, (4) two of wheat and mustard, (5) two of oats and mustard, (6) one having soil only. After the seeds had germinated they were thinned out so that in each pail there remained only 10 plants. In the mustard series a mustard plant was regarded as being in the same relationship as the oats and the wheat plants themselves.

To determine the amount of water loss a small platform scale, called a milk scale and weighing to ¼ ounce, was used. To measure the evaporating power of the air, a standardized form of cylindrical atmometer was employed. Maximum and minimum temperatures for each day were obtained directly from the chart of a recording thermograph. The data showing the evaporating environment and temperature are given in table XIV. At the conclusion of the experiment, the dry weight of the tops of the cereals was secured. As the mustard matures much earlier than wheat and oats, it was not feasible to secure its dry weight.

The leaf area was determined once a week thruout the experiment by means of a polar planimeter. The transpiration rate was calculated on the basis of a square meter of leaf surface. Weighings to ascertain the amount of water loss were made three times a week. At the end of each weighing as much water as had been lost during the period was added. In this way the water content of the soil was at least approximately at its optimum for growth for a good portion of the time. In the present study the soil

surface was not covered with wax or with plasticine for it was deemed advisable to permit tillering to the fullest extent. The water loss during the early stages would of course be largely due to the evaporation from the soil surface. In a short time sufficient leaf tissue was formed so that water loss due to evaporation was considered negligible and was regarded as being the result of transpiration. Atmometer readings were made twice a day thruout the entire period. The evaporating environment for day and night periods could then be readily determined

EXPERIMENTAL RESULTS

The data in this publication are derived from four series of culture: (1) wheat, (2) oats, (3) mustard, (4) soil. In the wheat series two cultures contained wheat alone, two a mixture of wheat and mustard. For the oats series there were two cultures of oats and two of oats and mustard. The mustard series had only the one culture and the same was true for the soil. The number of cereal plants to start out was chosen and so arranged as to meet conditions as similar as possible to those present in field growth. The series were also planned to show the effect of crowding the members of the same species. This could not be done in each case as plants in certain cultures were eliminated. In the experiments which are described in the pages following, the conditions under which the plants were grown were the same thruout.

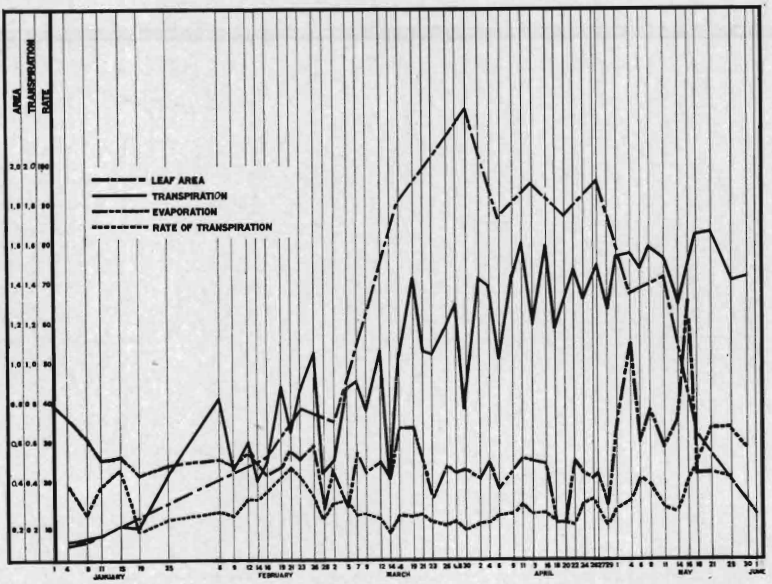

Fig. 1. Culture I, wheat. Showing leaf area evaporation, actual transpiration and rate of transpiration thruout the period of growth.

TABLE I. CULTURE I—WHEAT.

Date	No. of plants	No. of leaves	Leaf area	Water loss (grams)	Water loss CM^2H
Jan. 4,	7	90	639.00	77.94	19.33
8	7	100	710.00	85.05	12.47
11	7	100	710.00	99.22	19.36
15	7	100	710.00	177.18	23.97
19	7	150	2,382.00	155.92	7.43
25	7	150	2,382.00	446.49	10.82
Feb. 6	7	150	2,382.00	843.39	13.64
9	7	199	4,915.30	481.25	12.10
12	7	199	4,915.30	616.59	17.41
14	7	199	4,915.30	411.07	17.45
16	7	146	5,685.24	538.65	19.72
19	7	146	5,685.24	921.37	22.42
21	7	146	5,685.24	680.40	24.93
23	7	202	8,261.80	907.20	22.90
26	7	202	8,261.80	1,091.47	18.39
28	7	202	8,261.80	467.77	11.80
Mar. 2	7	140	7,420.00	545.73	15.99
5	7	140	7,420.00	914.28	16.61
7	7	140	7,420.00	949.72	12.68
9	7	230	12,903.00	822.15	13.28
12	7	230	12,903.00	1,098.54	11.81
14	7	230	12,903.00	439.42	7.08
16	7	266	18,518.92	1,084.38	12.19
19	7	266	18,518.92	1,460.02	10.92
21	7	266	18,518.92	1,105.65	12.42
23	7	344	20,791.36	1,077.30	10.81
26	7	344	20,791.36	1,204.87	9.23
28	7	344	20 791.36	1,346.62	11.33
30	7	322	23,319.24	822.15	7.66
April 2	7	322	23,319.24	1,460.02	9.63
4	7	322	23,319.24	1,417.50	10.65
6	7	312	17,858.88	1,048.95	12.27
9	7	312	17,858.88	1,488.37	13.20
11	7	312	17,858.88	1,620.12	16.00
13	7	264	19,435.68	1,219.05	13.02
16	7	264	19,435.68	1,615.95	13.21
18	7	264	19,435.68	1,204.87	10.88
20	7	320	17.792.00	.....	.....
22	7	320	17,792.00	1,502.55	9.74
24	7	320	17,792.00	1,375.50	16.10
26	7	320	17,792.00	1,539.90	17.67
27	7	324	19,699.20	.....	.....
28	7	324	19,699.20	1,304.10	9.35
May 1	7	324	19,699.20	1,587.60	14.17
4	7	290	14,123.00	1,587.60	17.81
6	7	290	14,123.00	1,502.55	22.20
8	7	290	14,123.00	1,615.95	20.08
11	7	344	14 585.60	1,559.25	14.85
14	7	344	14,585.60	1,360.80	13.91
16	7	344	14,585.60	1,686.82	20.65
18	7	153	6,732.00	.....	.....
21	7	153	6,732.00	1,729.35	35.61
25	7	97	4,322.32	1,474.20	35.60
30	7	97	4,322.32	1,516.72	29.30
June 1	7	64	2,426.88	.....	.....

In table I the dates when observations were made, the number of plants, the number of leaves, the total area in sq. cm., the actual water loss in grams and the water loss in grams per meter of leaf surface per hour are given in order. From the beginning there was an increase in the leaf area up to March 2, when there was a marked decrease. However, there was an intensive growth in the following week. The evaporation rate was also rather high. On March 30 the leaf area attained its maximum for the entire period (approximately 2.3 sq. meters). During the period from March 9 to March 30 there was much stooling and growth was very active. From April 20 until June 1, when the fruit was mature, there was a big drop in the extent of the leaf surface to the point where it was about the same as on January 19.

Considering the course of actual transpiration during the progress of the experiment, there was a general agreement between the increase in the leaf surface and in transpiration itself. It will be remembered that the plants were weighed three times a week. The leaf area was calculated once a week.

In examining the graph, fig 1, it is noticed that mamimum water loss did not occur until May 21. During the early part of May the evaporating environment, as measured by the standardized atmometer, was very high. The rate of transpiration during the latter part of May was 35 grams per meter of leaf surface per hour. Other interesting features may be gained by an examination of the graph.

In Culture II there were 5 wheat plants and 4 mustard plants with a total area at the time of the first reading respectively, 672.6 sq. cm. and 461.32 sq. cm., and a total leaf area of 1,133.92 sq. cm. The number of wheat plants remained the same thruout but the mustard plants fell off so that on April 26 there was only one plant and on May 18 the mustard had been entirely eliminated. The course of growth can be followed by examining fig. 2. During the early history of the wheat and the mustard of the series there was a slow growth until the first week in February. For the remainder of the month there was a rapid development for both the wheat and the mustard and on February 23 the mustard had its maximum area; again on April 6 the area was almost as much. After that time there was marked decrease.

Culture II had its maximum leaf area on April 13, about two weeks later than is the case of Culture I, wheat only, even tho the leaf areas were practically the same on January 4. There was also a considerable difference 7633 sq. cm., in the maximum leaf area acquired as well as in the time consumed in reaching this maximum.

The graph (fig. 2), shows that after February 6 the two curves of leaf area and actual transpiration remained in the same general latitude thruout. About the middle of April both the leaf area

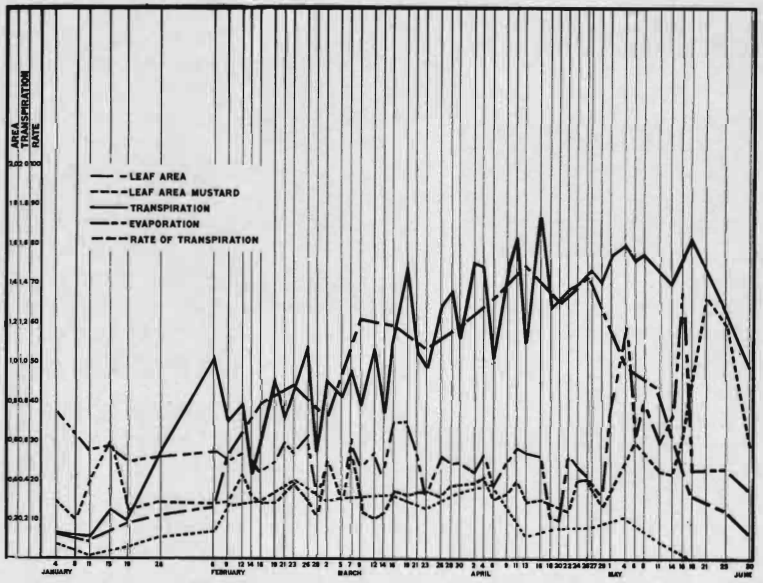

Fig. 2, culture II, wheat and mustard, showing leaf area, actual transpiration, evaporation and rate of transpiration, thruout the period of growth.

and actual transpiration had attained their maximum. Altho during the next month the grain became much taller, still there was no increase in the leaf area. By May 1 every head of grain had been formed and altho the maximum leaf area occurred later in this culture than in Culture I, the period for maturation became less.

The amount of water lost for a standard leaf surface in Culture II was greater than for the first culture, at least in the majority of cases. The highest rate listed occurred during the latter part of May. Of course the evaporation was high but it will be remembered that the heading-out took less time.

CULTURE III—WHEAT

As the environmental conditions were the same in each case, Culture III could be looked upon in much the same light as Culture I, except that 10 plants were used instead of 7. In this way it was possible to determine to what extent a wheat plant would compete with another plant of the same species and variety. The first readings of the present series showed a greater number of leaves with a resulting higher leaf area and water loss. This was not the case after the first week in February, even tho the number of leaves did not fall below those in Culture I until March 23. At that time two plants in the center had been crowded out. The highest transpiration occured on March 21 with a water out-go of 1,545.07 cc. The rate of transpiration per

TABLE II. SERIES I—CULTURE II—WHEAT AND MUSTARD.

Date	No. of wh. pl.	No. of wh. lvs.	Total area wheat	No. of mus pl.	No. of mus. lvs.	Total area mus.	Total area wh. and mus.	Water loss (grams)	Water loss GM^2H
January									
4	5	95	672.60	4	21	461.32	1,133.92	113.40	15.86
8	5	95	672.60	3	21	461.32	1,133.92	113.40	10.42
11	5	87	615.96	3	13	184.60	800.56	113.40	19.70
15	5	87	615.96	3	13	184.60	800.56	248.04	29.80
18	5	136	1,419.84	3	13	452.40	1,872.24	219.69	13.30
26	5	136	1,419.84	3	13	887.90	2,307.74	567.00	14.20
February									
6	5	136	1,419.84	3	20	1,366.00	2,785.84	1,027.68	14.65
9	5	185	2,556.70	3	28	3,057.60	5,614.30	694.57	15 30
12	5	185	2,556.70	3	28	3,057.60	5,614.30	822.15	21.75
14	5	185	2,556.70	3	28	3,057.60	5,614.30	439.42	16.31
16	5	214	5,024.72	3	23	3,284.40	8,451.92	595.35	14.66
19	5	214	5,024.72	3	23	3,284.40	8,451.92	921.37	15.15
21	5	214	5,024.72	3	23	3,284.40	8,451.92	722.92	17.81
23	5	129	5,289.00	3	17	4,336.70	9,625.70	935.55	20.21
26	5	129	5,289.00	3	17	4,336.70	9,625.70	1,056.03	15.21
28	5	129	5,289.00	3	17	4,336.70	9,625.70	517.38	11.16
March									
2	5	140	4,502.40	3	20	3,206.00	7,708.40	914.28	24.65
5	5	140	4,502.40	3	20	3,206.00	7,708.40	900.09	16.20
7	5	140	4,502.40	3	20	3,206.00	7,708.40	970.98	26.21
9	5	161	9,338.00	3	15	3,453.00	12,791.00	807.97	13.18
12	5	161	9,338.00	3	15	3,453.00	12,791.00	1,077.30	11.71
14	5	161	9,338.00	3	15	3,453.00	12,791.00	751.21	12.23
16	5	179	9,025.18	3	15	3,669.00	12,694.18	1,105.65	18.11
19	5	179	9,025.18	3	15	3,669.00	12,694.18	1,523.79	16.70
21	5	179	9,025.18	3	15	3,669.00	12,694.18	1,048.95	17.20
23	5	150	9,615.00	3	13	2,917.20	12,532.20	999.33	16.42
26	5	150	9,615.00	3	13	2,917.20	12,532.20	1,296.99	16.10
28	5	150	9,615.00	3	13	2,917.20	12,532.20	1,389.15	19.06
30	5	155	7,998.00	3	19	3,990.00	11,988.00	1,077.30	19.10
April									
2	5	155	7,998.00	3	19	3,990.00	11,988.00	1,523.79	19.89
4	5	155	7,998.00	3	19	3,990.00	11,988.00	1,502.55	22.00
6	5	180	9,792.00	2	22	4,294.40	14,086.40	1,020.60	15.10
9	5	180	9,792.00	2	22	4,294.40	14,086.40	1,488.37	16.76
11	5	180	9,792.00	2	22	4,294.40	14,086.20	1,679.73	20.91
13	5	198	14,572.80	2	11	1,113.20	15,686.00	1,105.65	14.59
16	5	198	14,572.80	2	11	1,113.20	15,686.00	1,747.20	14.91
18	5	198	14,572.80	2	11	1,113.20	15,686.00	1,299.96	14.41
20	5	206	11,449.48	2	23	1,656.00	13,105.48	.....	.....
22	5	206	11,449.48	2	23	1,656.00	13,105.48	1,389.15	12.18
24	5	206	11,449.48	2	23	1,656.00	13,105.48	1,417.50	22.50
26	5	206	11,449.48	2	23	1,656.00	13,105.48	1,445.50	22.50
27	5	224	13,699.84	1	30	1,733.40	14,838.88	.....	.....
29	5	224	13,699.84	1	30	1,733.40	14,838.88	1,417.50	13.41
May									
1	5	224	13,699.84	1	30	1,733.40	14,838.88	1,573.42	18.60
4	5	167	8,132.90	1	32	2,277.12	10,410.02	1,615.95	24.60
6	5	167	8,132.90	1	32	2,277.12	10,410.02	1,530.90	30.61
8	5	167	8,132.90	1	32	2,277.12	10,410.02	1,573.42	26.55
11	5	240	8,596.80	1	33	700.26	9,297.06	1,488.37	22.85
14	5	240	8 596.80	1	33	700.26	9,297.06	1,417.50	22.05
16	5	240	8,596.80	1	33	700.26	9,297.06	1,672.65	32.00
18	5	81	3,564.00	...	10	103.00	3,667.00	.....	.....
21	5	81	3,564.00	...	10	103.00	3,667.00	1,474.20	55.83
25	5	61	2,690.01	...	..	.....	2,690.01	1,275.75	49.45
30	5	61	2,690.01	...	..	.....	2,690.01	935.55	28.90
June									
1	5	21	795.90	...	..	.....	795.90	.....	.....

TABLE III. CULTURE III—WHEAT.

Date	No. of plants	No. of leaves	Total area	Water loss (grams)	Water loss GM^2H
Jan. 4,	10	153	1,676.88	219.69	20.70
8	10	153	1,676.88	283.50	17.60
11	10	172	1,885.12	248.04	18.26
15	10	172	1 885.12	439.38	23.25
19	10	174	3,039.68	382.72	14.30
26	10	194	3,204.88	616.59	11.12
Feb. 6	10	194	3,204.88	737.10	8.88
9	10	217	4,782.68	439.42	11.31
12	10	217	4,782.68	552.82	16.05
14	10	217	4,782.68	311.85	13.54
16	10	274	6,439.00	418.14	13.52
19	10	274	6,439.00	623.70	13.45
21	10	274	6,439.00	503.19	16.28
23	10	303	7,120.50	574.08	17.50
26	10	303	7,120.50	687.48	13.02
28	10	303	7,120.50	340.20	9.97
Mar. 2	10	194	4,958.64	715.83	30.00
5	10	194	4,958.64	574.08	16.09
7	10	194	4,958.64	637.87	26.80
9	10	222	6,304.80	637.87	21.08
12	10	222	6.304.80	793.80	17.46
14	10	222	6,304.80	382.72	12.63
16	10	216	10,808.64	666.62	12.82
19	10	216	10,808.64	990.09	12.60
21	10	216	10,808.64	1,545.07	29.50
23	10	199	6,333.68	510.30	16.88
26	10	199	6,333.68	708.75	17.78
28	10	199	6,333.68	765.45	21.20
30	10	209	7,586.70	652.05	17.95
April 2	10	209	7,586.70	567.77	11.89
4	10	209	7,586.70	737.10	17.05
6	10	198	8,147.70	396.90	10.15
9	10	198	8,147.70	751.27	14.60
11	10	198	8,147.70	822.15	17.71
13	10	204	6,448.44	666.22	21.40
16	10	204	6,448.44	765.45	18.82
18	10	204	6.448.44	737.10	20.00
20	10	234	7,464.60	.....	.....
22	10	234	7,464.60	708.75	10.90
24	10	234	7,464.60	765.45	21.35
26	10	234	7,464.60	652.05	17.82
27	10	237	8,626.80	.....	.....
29	10	237	8,626.80	625.05	10.62
May 1	10	237	8,626.80	708.75	14.40
4	10	193	6,330.40	737.10	18.49
6	10	193	6,330.40	793.80	26.15
8	10	193	6,330.40	822.15	22.76
11	10	225	8,050.50	822.15	14.20
14	10	225	8,050.50	737.10	13.65
16	10	225	8,050.50	907.20	20.12
18	10	124	3,670.40	.....	.....
21	10	124	3,670.40	1,389.15	51.10
25	10	82	1,787.60	850.50	50.10
30	10	82	1,787.60	807.97	37.40

hour (GM^2H) was fairly uniform thruout. From January 4 until May 21 it ranged from 8.88 grams to 29.50 grams and on May 21 the rate was 51 grams. The data showing the course taken thruout have been measured by the number of leaves, the leaf area, the total water loss and the water lost per square meter of leaf surface per hour. These are given in table III. The graph, fig. 3, brings out the various features.

CULTURE IV—WHEAT AND MUSTARD

In Culture IV, containing wheat and mustard, 10 wheat plants and 2 mustard plants were involved. On April 29 one of the mustard plants was eliminated and by May 4 the remaining plant succumbed. It is interesting to note that the areas of both the wheat and the mustard of the present series did not come up to the mark of the previous culture. The maximum area was reached on April 6 as against March 16. The mustard had its greatest area on February 9.

As in the other cultures the actual transpiration increased materially up to February 6. There was more or less of a fluctuation until March 18. In a general way the rate of transpiration was similar to that of the previous culture where wheat alone was grown. The maximum rate occurred on May 25 as compared with May 21 where no weeds were associated with the wheat. Specific data are presented in table IV. In fig. IV the results have been shown graphically.

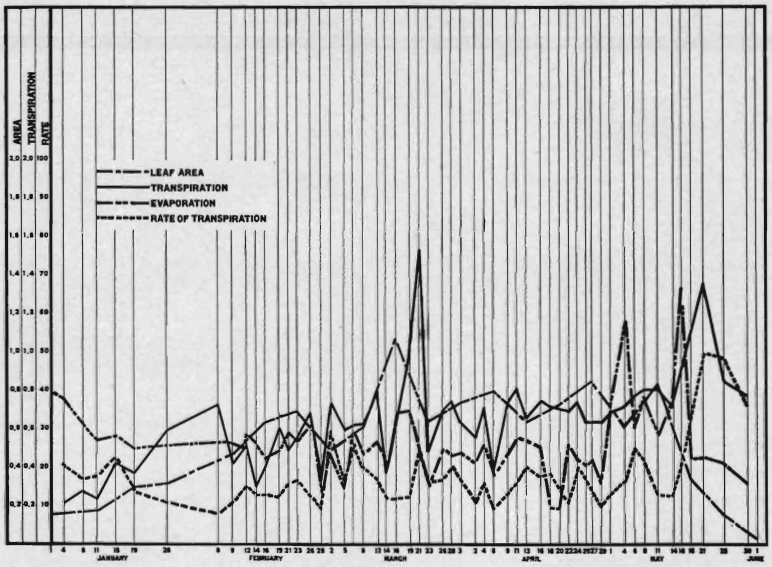

Fig. 3, culture III, wheat, showing leaf area, actual transpiration, evaporation and rate of transpiration thruout the period of growth.

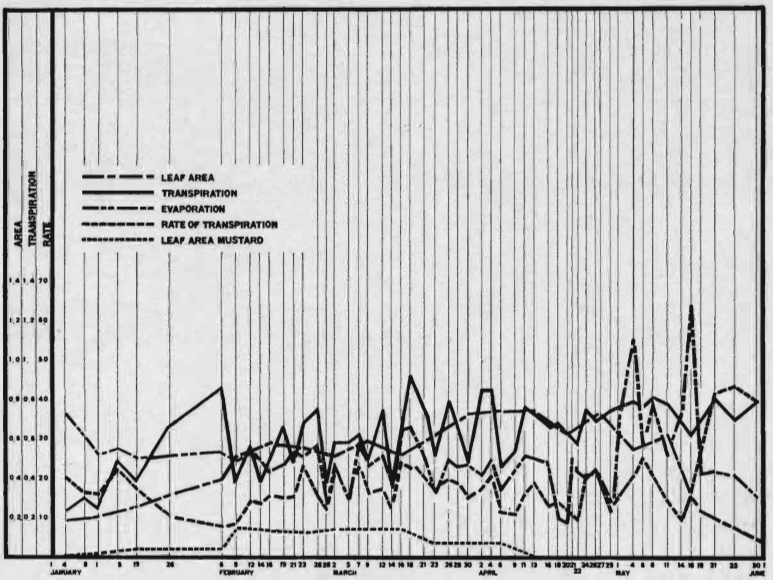

Fig. 4, culture IV, wheat and mustard. Leaf area, transpiration, evaporation, rate of transpiration and leaf area thruout the period of growth.

In the formulations given for the wheat series much has been made of the period of the maximum leaf area and maximum transpiration. The time of maximum rate has been brought out as well. The following data (table V) were prepared with that point of view.

The data in table V show that the greatest leaf area for wheat with mustard was attained later than where the wheat was grown alone.

It would be expected that maximum leaf area and maximum transpiration would coincide. In Culture III the two took place approximately at the same time while in Culture II the maximum wheat area came about on April 13 which of course is not far in advance of April 16, the time of maximum transpiration value. There may have been conflicting agents, which could not under the conditions of the experiment be fully reckoned with. As the newly formed leaves transpire more actively, it is easy to see how a status of this kind would be present.

In the same series it is interesting to note that where there were 7 wheat plants, there was a better development thruout than where 10 plants were used whether of the same species or not. Competition may be as keen between members of the same species as with different species Having this in mind it was thought advisable to ascertain this point on the basis of maximum height, dry weight produced and kilograms of water used. The data have been given in the following table.

TABLE IV. CULTURE IV—WHEAT AND MUSTARD.

Date	No. of wh. pl.	No. of wh. lvs.	Total area wheat	No. of mus. pl.	No. of mus. lvs.	Total area mus.	Total area mus. and wh.	Water loss (grams)	Water loss GM^2H
January									
4	10	157	1,719.15	2	9	197.64	1,916.79	248.04	20.53
8	10	157	1,719.15	2	9	197.64	1,916.79	326.03	17.75
11	10	175	1,918.00	2	10	209.00	2,127.00	269.32	17.58
15	10	175	1,918.00	2	10	209.00	2,127.00	510.27	23.60
19	10	180	1,973.00	2	10	643.60	2,616.60	396.90	17.28
26	10	180	3,006.00	2	10	643.60	3,649.60	680.40	10.78
February									
6	10	180	3,480.00	2	10	643.60	4,123.60	893.02	8.36
9	10	185	4,082.95	2	13	1,417.00	5,499.95	382.72	8.61
12	10	185	4,082.95	2	13	1,417.00	5,499.95	609.52	15.41
14	10	185	4,082.95	2	13	1,417.00	5,499.95	382.72	14.52
16	10	212	4,977.76	2	13	1,344.20	6,321.96	524.47	17.30
19	10	212	4,977.76	2	13	1,344.20	6,321.96	737.10	16.20
21	10	212	4,977.76	2	15	1,344.20	6,321.96	518.17	17.07
23	10	211	4,954.28	2	15	1,198.50	6,152.78	680.40	24.15
26	10	211	4,954.28	2	15	1,198.50	6,152.78	793.80	17.37
28	10	211	4,954.28	2	15	1,198.50	6,152.78	382.72	12.92
March									
2	10	172	4,392.88	2	13	1,302.86	5,695.74	637.87	23.30
5	10	172	4,392.88	2	13	1,302.86	5,695.74	637.87	15.51
7	10	172	4,392.88	2	13	1,302.86	5,695.74	659.13	24.10
9	10	180	5,112.00	2	14	1,362.20	6,474.20	510.30	16.42
12	10	180	5,112.00	2	14	1,362.20	6,474.20	786.69	16.90
14	10	180	5,112.00	2	14	1,362.20	6,474.20	396.90	12.76
16	10	155	4,402.00	2	17	1,383.80	5,785.80	722.92	26.02
18	10	155	4,402.00	2	17	1 383.80	5,785.80	1,013.49	24.40
21	10	155	4,402.00	2	17	1,383.80	5,785.80	652.05	23.52
23	10	202	6,128.68	2	17	660.28	6,788.96	567.00	17.41
26	10	202	6,128.68	2	17	660.28	6,788.96	857.58	20.05
28	10	202	6,128.68	2	17	660.28	6,788.96	737.10	19.05
30	10	198	7,175.52	2	15	600.90	7,776.42	510.30	14.54
April									
2	10	198	7,175.52	2	15	600.90	7,776.42	928.44	18.00
4	10	198	7,175.52	2	15	600.90	7,776.42	921.37	20.75
6	10	202	7,316.44	2	21	712.32	8,028.76	481.95	12.50
9	10	202	7,316.44	2	21	712.32	8,028.76	609.52	12.04
11	10	202	7,316.44	2	21	712.32	8,028.76	822.15	17.99
13	10	181	5,719.60	2	17	218.11	7,937.71	793.90	20.42
16	10	181	5,719.60	2	17	218.11	7,937.71	722.92	14.45
18	10	181	5,719.60	2	17	218.11	7,937.71	737.10	16.20
20	10	194	6,192.48	2	10	170.40	6,862.88	.....	.....
22	10	194	6,192.48	2	10	170.40	6,862.88	637.87	10.65
24	10	194	6,192.48	2	10	170.40	6,862.88	779.62	23.18
26	10	194	6,192.48	2	10	170.40	6,362.88	737.10	22.84
27	10	210	7,644.00	2	18	218.16	7,862.16	.....	.....
29	10	210	7,644.00	2	18	218.16	7,862.16	793.80	14.02
May									
1	10	210	7,644.00	2	18	218.16	7,862.16	822.15	18.32
4	10	172	6,054.40	1	8	53.60	6,108.00	850.50	22.09
6	10	172	6,054.40	...	8	53.60	6,108.00	822.15	28.00
8	10	172	6,054.40	...	8	53.60	6,108.00	850.50	24.50
11	10	198	7,072.56	...	....	.....	7,072.56	836.32	16.42
14	10	198	7,072.56	...	....	.....	7,072.56	481.95	10.18
16	10	198	7,072.56	...	....	.....	7,072.56	708.75	19.90
18	10	89	2,630.84	...	....	.....	2,630.84	.....	.....
21	10	89	2,630.84	...	....	.....	2,630.84	878.85	45.20
25	10	77	1,663.20	...	....	.....	1,663.20	751.27	47.60
30	10	77	1,663.20	...	....	.....	1,663.20	864.67	42.85
June									
1	10	30	573.00	...	....	.....	573.00	.....	.....

TABLE V. TIME AT WHICH THE WHEAT AND WHEAT WITH MUSTARD CULTURES ATTAINED THEIR MAXIMUM VALUES.

Designation	Maximum leaf area		Maximum transpiration	Maximum rate
	Wheat	Mustard		
No. I	March 30		May 21	May 21
No. II	April 13	Feb. 23	April 16	May 21
No. III	March 16		March 21	May 21
No. IV	April 27	Feb. 9	March 18	May 25

In the data submitted the results of the competition are made clearer for the reason that they are cumulative. Comparisons are logically made between Cultures I and II and Cultures III and IV. As far as height is concerned there was not very much difference. Where there were a large number of plants or too many plants growing on a given area, they were shorter. The dry weight, which has often been used as a means of measuring tissue production, was found to be 127.8 grams for the wheat alone, while the wheat in the mustard produced 97.61 grams. In the first case cited less water was also used. In the other cultures, III and IV, there was not much of a variance in height. The pure wheat culture produced 68.10 grams of dry tissue while the mixed culture formed only 57.95 grams of dry weight material. However, the amount of water used was practically the same.

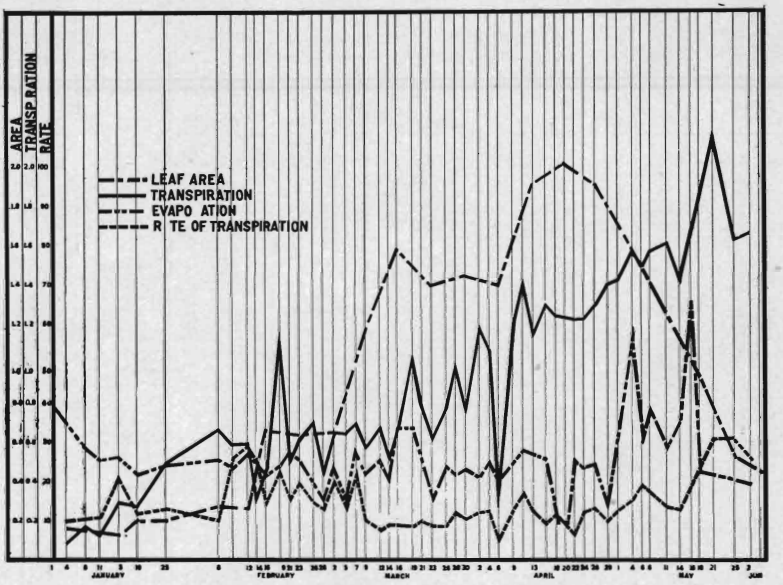

Fig. 5, culture V, oats. Leaf area, actual transpiration, evaporation and rate of transpiration thruout the period of growth.

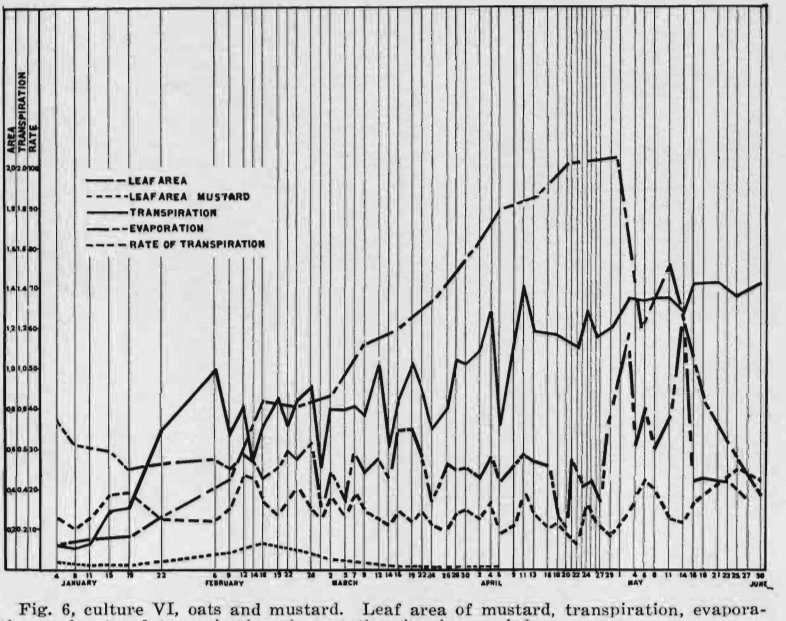

Fig. 6, culture VI, oats and mustard. Leaf area of mustard, transpiration, evaporation and rate of transpiration thruout the ripening period.

From the work presented upon the wheat series it is clear that weeds retard the development of the crop with which they are associated by increasing the amount of water given off for unit area and also by decreasing the dry weight.

Series II—Oats

In the oats series, the general procedure and methods employed were the same as were used in the wheat series. Readings were taken at the same time as with wheat.

CULTURE V

This particular culture contained 7 oat plants. The number of leaves gradually increased from 54 on Jan. 4 to 384 on April 26. The progress of development may be followed by an examination of the data given in table VII, or by the graph, fig. 5.

TABLE VI. HEIGHT, DRY WEIGHT AND TOTAL TRANSPIRATION OF WHEAT GROWN WITH AND WITHOUT MUSTARD FOR GROWING PERIOD, JAN. 1 to JUNE 1.

Culture	Maximum height of culture (cm.)		Dry weight of cereals (gm.)	Water used (Kilograms)
	Wheat	Mustard		
No. I	110	....	127.80	53.30
No. II	109	66	97.61	54.56
No. III	86	....	68.10	33.66
No. IV	90	31	57.95	33.86

TABLE VII. CULTURE V—OATS.

Date	No. of plants	No. of leaves	Leaf area	Water loss (grams)	Water loss GM^2H
Jan. 4	7	54	1,739.88	113.40	10.30
8	7	54	1,739.88	184.22	11.03
11	7	54	1,739.88	141.75	11.32
15	7	43	1,385.46	304.75	21.55
19	7	70	2,074.80	283.50	12.21
26	7	71	2,104.44	489.03	13.46
Feb. 6	7	98	2,821.00	772.53	10.61
9	7	98	2,821.00	602.43	26.35
12	7	98	2,783.20	595.35	29.60
14	7	98	2,783.20	347.28	25.95
16	7	116	6,693.20	467.77	14.53
19	7	116	6,693.20	1,105.65	22.95
21	7	116	6,693.20	517.38	16.10
23	7	126	6,458.76	623.70	20.15
26	7	126	6,458.76	701.64	15.08
28	7	126	6,458.76	425.25	13.70
Mar. 2	7	111	6,570.08	652.05	20.69
5	7	111	6,570.08	652.05	13.76
7	7	111	6,570.08	708.75	22.40
9	7	176	11,770.88	581.17	10.29
12	7	176	11,770.88	680.40	8.02
14	7	176	11,700.88	538.65	9.53
16	7	268	15,897.76	708.75	9.30
19	7	268	15,897.76	1,027.68	9.00
21	7	268	15,897.76	793.80	10.39
23	7	299	13,933.40	630.78	9.44
26	7	299	13,933.40	779.62	8.90
28	7	299	13,933.40	992.25	12.46
30	7	282	14,551.20	737.10	11.02
April 2	7	282	14,551.20	1,190.70	12.60
4	7	282	14,551.20	1,077.30	12.99
6	7	324	14,048.64	368.55	5.45
9	7	324	14,048.64	1,204.87	13.60
11	7	324	14,048.64	1,417.50	17.70
13	7	342	19,220.40	1,148.17	12.70
16	7	342	19,220.40	1,304.10	10.15
18	7	342	19,220.40	1,247.40	12.05
20	7	356	20,227.92	.....	.....
22	7	356	20,227.92	1,233.22	7.02
24	7	356	20,227.92	1,219.05	12.51
26	7	384	19,200.40	1,304.10	13.86
27	7	384	19,200.40	.....	.....
29	7	384	19,200.40	1,417.50	10.38
May 1	7	384	19,200.40	1,431.67	13.10
4	7	361	15,847.90	1,587.60	15.90
6	7	361	15,847.90	1,502.55	19.80
8	7	361	15,847.90	1,587.60	17.56
11	7	376	15,949.92	1,615.95	14.09
14	7	376	15,949.92	1,431.67	13.38
16	7	376	15,949.92	1,672.65	18.72
18	7	208	9,461.32	.....	.....
21	7	208	9,461.32	2,154.60	31.58
25	7	140	5,356.40	1,630.12	31.69
30	7	140	5,356.40	1,672.65	26.02
June 1	7	131	4,632.16	.....	.....

TABLE VII. CULTURE VI—OATS AND MUSTARD.

Date	No. of oat pl.	No. of oat lvs.	Total area oats	No. of mus. pl.	No. of mus. lvs.	Total area mus.	Total area mus. and oats	Water loss (grams)	Water loss GM^2H
January									
4	7	29	933.80	3	16	348.80	1,282.60	127.57	15.76
8	7	29	933.80	3	16	348.80	1,282.60	127.57	10.35
11	7	40	1,288.00	3	14	217.00	1,505.00	141.75	13.09
15	7	40	1,288.00	3	14	217.00	1,505.00	297.66	19.10
19	7	40	1.548.00	3	14	217.00	1,765.00	304.74	19.56
26	7	63	2,438.10	3	14	433.72	2,871.82	715.83	14.48
February									
6	7	63	2,438.10	3	14	433.72	2,871.82	1,013.49	12.20
9	7	85	3,748.50	3	18	856.80	4,605.30	680.40	18.31
12	7	85	3,748.50	3	18	856.80	4,605.30	900.88	24.11
14	7	85	3,748.50	3	18	856.80	4,605.30	517.38	23.31
16	7	124	7,162.24	3	13	1,341.60	8,503.84	701.65	17.13
19	7	124	7,162.24	3	13	1,341.60	8,503.84	871.74	14.20
21	7	124	7,162.24	3	13	1.341.60	8,503.84	701.64	17.12
23	7	138	7,079.40	3	15	1,197.00	8,276.40	857.58	21.56
26	7	138	7,079.40	3	15	1,197.00	8,276.40	928.44	15.55
28	7	138	7,079.40	3	15	1,197.00	8,276.40	510.30	12.84
March									
2	7	140	8,316.00	3	8	563.52	8,879.52	810.04	19.00
5	7	140	8,316.00	3	8	563.52	8,879.52	807.97	13.72
7	7	140	8,316.00	3	8	563.52	8,879.52	810.04	19.10
9	7	164	10,968.32	3	7	360.50	11,328.82	779.62	14.32
12	7	164	10,968.32	3	7	360.50	11,328.82	1,020.60	12.50
14	7	164	10,968.32	3	7	360.50	11,328.82	609.52	11.19
16	7	253	12,078.22	3	6	213.00	13,291.22	857.52	14.65
18	7	253	12,078.22	3	6	213.00	13,291.22	1,048.95	11.85
21	7	253	12,078.22	3	6	213.00	13,291.22	907.20	15.36
23	7	288	13,449.60	3	3	82.80	13,532.40	715.83	10.80
26	7	288	13,449.60	3	3	82.80	13,532.40	822.15	9.63
28	7	280	13,449.60	3	3	82.80	13,532.40	1,077.30	13.91
30	7	280	14,448.00	2	3	56.10	14,500.10	1,048.95	15.05
April									
2	7	280	14,448.00	2	3	56.10	14,500.10	1,105.65	12.10
4	7	280	14,448.00	2	3	56.10	14,500.10	1,304.10	15.80
6	7	344	18,066.88	2	3	58.50	18,125.38	722.92	8.30
9	7	344	18,066.88	...	3	58.50	18,125.38	1,190.70	10.41
11	7	344	18,066.88	...	3	58.50	18,125.38	1,403.32	13.57
13	7	328	18,466.40	...	....	.....	18,466.40	1,204.87	13.61
16	7	328	18,466.40	...	....	.....	18,466.40	1,190.70	9.77
18	7	328	18,466.40	...	....	.....	18,466.40	1,190.70	11.91
20	7	360	20,592.00	...	....	.....	20,592.00	.....	.....
21	7	360	20,592.00	...	....	.....	20,592.00	1,162.35	5.90
22	7	360	20,592.00	...	....	.....	20,592.00	1,299.92	16.10
24	7	360	20,592.00	...	....	.....	20,592.00	1,176.52	11.70
26	7	360	20 805.00	...	....	.....	20,805.00	.....	.....
29	7	360	20,805.00	...	....	.....	20,805.00	1,247.40	8.44
May									
1	7	360	20,805.00	...	....	.....	20,805.00	1,360.80	11.45
4	7	276	12,127.24	...	....	.....	12,127.44	1,360.80	17.90
6	7	276	12,127.44	...	....	.....	12,127.44	1,332.45	22.85
8	7	276	12,127.44	...	....	.....	12,127.44	1,360.80	19.76
11	7	364	15,433.60	...	....	.....	15,433.60	1,360.80	12.80
14	7	364	15,433.60	...	....	.....	15,433.60	1,304.10	12.08
16	7–	364	15,433.60	...	....	.....	15,433.60	1,445.85	16.75
18	7	202	9,203.12	...	....	.....	9,203.12	.....	.....
21	7	202	9,203.12	...	....	.....	9,203.12	1,445.85	21.80
25	7	139	5,323.70	...	....	.....	5,323.70	1,360.80	26.65
30	7	139	5,323.70	...	....	.....	5,323.70	1,446.80	22.61
June									
1	7	104	3,411.20	...	....	.....	3,411.20	.....	.....

On April 6 the oats were just beginning to head out and by April 24 the process had been completed. After that time there was a decrease in the number of leaves but an increase in the water given off. This feature in itself emphasizes the need of a rather large amount of water during the time the grain is being formed. A large amount of water was transpired in May due to the high evaporating environment. The data are given in table VII, followed immediately by the graph.

CULTURE VI—OATS AND MUSTARD

Culture VI contained seven oat plants and three mustard plants and as far as general growth and development are comparable to Culture II of the wheat series. On March 30 the mustard plants had been reduced to two in number and by April 6 they had been eliminated entirely. At that time the mustards became heavily infested with mildew and this assisted in their destruction. The maximum area for the mustard occurred on February 16. Actual transpiration is characterized by the same general course as found in Culture V. It was very near its maximum when the greatest leaf area was recorded, April 26. Due to the early elimination of the mustard, the maximum transpiration during the heading-out stage was about the same as for the pure oats culture. The various features in the development as measured by leaf area and transpiration have been represented in the next graph, fig. VI.

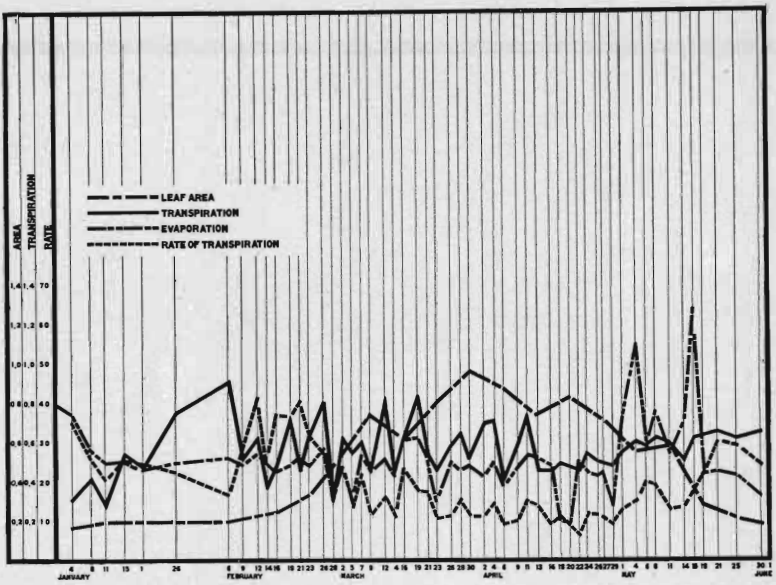

Fig. 7, culture VIII, oats. Leaf area, transpiration, evaporation and rate of transpiration thruout the period of growth.

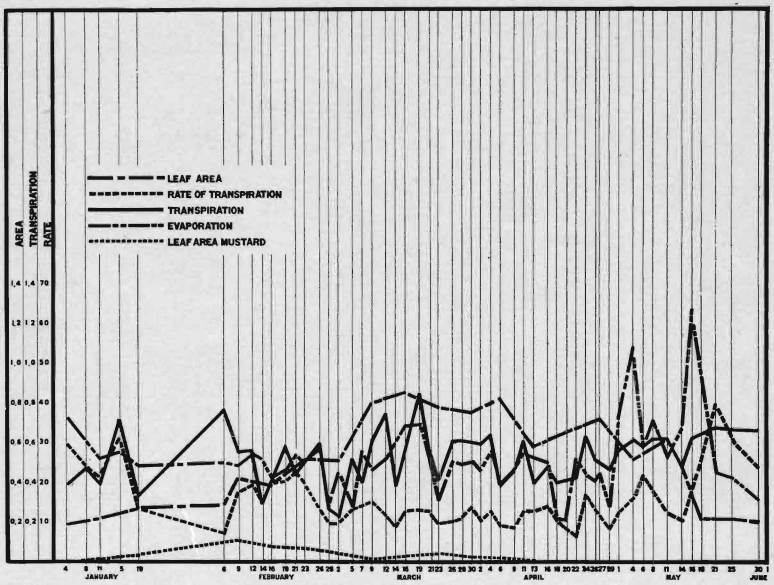

Fig. 8, culture VIII, oats and mustard. Leaf area, rate of transpiration, transpiration, evaporation, and leaf area of mustard thruout the period of growth.

CULTURE VII—OATS

In this culture 10 plants were grown. It became evident after the first part of February that the number was too great. However it was part of the problem to note the extent of competition between the same species as well as between different forms. There was less stooling in Culture VII than Culture V. The grain commenced to head out April 13, a week later than in Culture V. The greatest leaf area in Culture V was twice that attained for Culture VII. The number of leaves of Culture VII never exceeded 200 while in the other pure oats culture 384 leaves were developed from seven plants. The various features in the transpirational life history may be followed from the data submitted in table IX and from the graph following.

CULTURE VIII—OATS AND MUSTARD

In Culture VIII there were 10 oats plants and 4 mustard plants. The total number of oats leaves never exceeded 200. The number of mustard plants first decreased February 23; on May 11 two plants remained and on May 18 there was only one plant, while five days later all the mustard plants had succumbed.

The growth of the leaf area of the mustard was 912 sq. cm. by Feb. 9. From that time on there was a gradual drop until May 21 when the last plant was crowded out. Considering the total leaf tissue there was not sufficient leaf area for the mustard to vary

TABLE IX. CULTURE VII—OATS.

Date		No. of plants	No. of leaves	Total area	Water loss (grams)	Water loss GM^2H
Jan.	4	10	50	1,611.00	354.37	34.90
	8	10	50	1,611.00	439.42	28.30
	11	10	63	2,029.86	311.85	21.30
	15	10	63	2,029.86	637.87	24.20
	19	10	57	2,058.84	496.12	27.45
	26	10	57	2,058.84	793.80	22.31
Feb.	6	10	51	2,147.10	942.63	16.92
	9	10	51	2,147.10	559.89	32.10
	12	10	51	2,147.10	694.57	44.80
	14	10	51	2,147.10	382.72	27.29
	16	10	60	2,694.00	510.30	39.45
	19	10	60	2,694.00	751.27	38.80
	21	10	60	2.694.00	552.82	42.80
	23	10	79	3,962.64	708.75	35.40
	26	10	79	3,962.64	843.39	28.78
	28	10	79	3,962.64	340.20	17.80
Mar.	2	10	87	5,846.40	680.40	24.40
	5	10	87	5,846.40	623.70	14.82
	7	10	87	5,846.40	652.05	23.20
	9	10	111	7,770.00	481.95	12.91
	12	10	111	7,770.00	878.85	15.70
	14	10	144	7,770.00	453.60	12.20
	16	10	144	6,874.00	673.29	24.00
	19	10	144	6,874.00	907.20	18.33
	21	10	144	6,874.00	518.17	17.64
	23	10	184	85,928.00	481.95	11.70
	26	10	184	85,928.00	652.05	12.06
	28	10	184	85,928.00	715.83	14.61
	30	10	196	10,113.60	552.82	11.89
April	2	10	196	10,113.60	751.27	11.42
	4	10	196	10,113.60	758.34	13.18
	6	10	180	9.453.60	425.25	9.37
	9	10	180	9,453.60	652.05	10.92
	11	10	180	9,453.60	765.45	14.20
	13	10	200	7,944.00	481.95	12.65
April	16	10	200	7,944.00	481.95	9.19
	18	10	200	7,944.00	524.47	12.20
	20	10	196	8,937.60	.....	.....
	22	10	196	8,937.60	481.95	6.20
	24	10	196	8,937.60	581.17	13.28
	26	10	196	8,937.60	538.65	12.62
	27	10	200	7,594.00	.....	.....
	29	10	200	7,594.00	510.30	9.40
May	1	10	200	7,594.00	595.35	13.81
	4	10	141	6,189.90	652.05	16.22
	6	10	141	6,189.90	623.70	21.00
	8	10	141	6,189.90	680.40	19.35
	11	10	182	6,370.00	652.05	14.20
	14	10	182	6,370.00	595.35	13.95
	16	10	182	6,370.00	680.40	19.15
	18	10	94	2,944.08	.....	.....
	21	10	94	2,944.08	729.99	33.41
	25	10	83	2,219.42	680.40	32.46
	30	10	83	2,219.42	708.75	26.40
June	1	10	74	.....	.....	.....

TABLE X. CULTURE VIII—OATS AND MUSTARD.

Date	No. of oat pl.	No. of oat lvs.	Total area oats	No. mus pl.	No. mus lvs.	Total area mus.	Total area mus. and oats	Water loss (grams)	Water loss GM^2H
January									
6	10	58	1,867.60	4	20	206.40	2,074.00	396.90	30.27
8	10	58	1,867.60	4	20	206.40	2,074.00	510.30	25.85
11	10	65	2,093.00	4	20	240.00	2,333.00	396.90	23.60
15	10	65	2,093.00	4	20	240.00	2,333.00	758.34	31.30
19	10	65	2,365.50	4	20	576.00	2,922.50	368.55	14.31
February									
6	10	73	2,635.30	4	20	576.00	3,211.39	815.04	5.88
9	10	81	3,405.24	4	20	912.00	4,317.20	602.43	17.20
12	10	81	3,405.24	4	20	912.00	4,317.20	616.59	19.80
14	10	81	3,405.24	4	20	912.00	4,317.20	333.09	16.06
16	10	82	3,275.08	4	13	814.45	4,089.53	418.14	21.30
19	10	82	3,275.08	4	13	814.45	4,089.53	644.94	21.87
21	10	82	3,275.08	4	13	814.45	4,089.53	460.68	23.45
23	10	101	3,275.08	3	12	741.60	5,791.60	559.89	21.00
26	10	101	5,050.00	3	12	741.60	5,791.60	659.13	15.40
28	10	101	5,050.00	3	12	741.60	5,791.60	290.88	10.46
March									
2	10	75	5,010.00	3	9	543.60	5,553.60	255.15	9.64
5	10	75	5,010.00	3	9	543.60	5,553.60	559.89	14.05
7	10	75	5,010.00	3	9	543.60	5,553.60	418.14	15.70
9	10	124	8,290.64	3	8	413.20	8,703.84	680.40	16.30
12	10	124	8,290.64	3	8	413.20	8,703.84	793.80	12.66
14	10	124	8,290.64	3	8	413.20	8,703.84	389.79	9.34
16	10	141	8,375.40	3	9	479.34	8,854.74	602.42	14.15
19	10	141	8,375.40	3	9	479.34	8,854.74	921.37	14.42
21	10	141	8,375.40	3	9	479.34	8,854.74	602.43	14.16
23	10	159	7,822.80	3	11	622.16	8,444.96	425.25	10.55
26	10	159	7,822.80	3	11	622.16	8,444.96	623.70	11.73
28	10	159	7,822.80	3	11	622.16	8,444.96	623.70	12.98
30	10	145	5,628.90	3	13	585.00	8,213.90	609.52	15.75
April									
2	10	145	5,628.90	3	13	585.00	8,213.90	595.35	11.30
4	10	145	5,628.90	3	13	585.00	8,213.90	637.87	13.60
6	10	161	8,462.16	3	25	468.00	8,930.16	396.90	9.26
9	10	161	8,462.16	3	25	468.00	8,930.16	481.95	8.57
11	10	161	8,462.16	3	25	468.00	8,930.16	694.57	13.64
13	10	106	4,208.20	3	15	230.40	6,438.60	396.90	13.34
16	10	106	4,208.20	2	15	230.40	6,438.60	496.12	14.00
18	10	106	4,208.20	3	15	230.40	6,438.60	396.90	10.00
20	10	157	7,174.90	3	11	216.04	7,390.94	.....	.....
22	10	157	7,174.90	3	11	216.04	7,390.94	425.25	6.66
24	10	157	7,174.90	3	11	216.04	7,390.94	694.57	19.40
26	10	157	7,174.90	3–	11	216.04	7,390.94	552.82	15.78
27	10	200	7,592.00	3	16	115.52	7,707.52	.....	.....
29	10	200	7,592.00	3	16	115.52	7,707.52	510.30	9.33
May									
1	10	200	7,592.00	3	16	115.52	7,707.52	609.52	13.84
4	10	127	5,570.22	3	12	91.68	5,661.90	680.40	19.16
6	10	127	5,570.22	3	12	91.69	5,661.90	652.05	23.95
8	10	127	5,570.22	3	12	91.68	5,661.90	680.40	21.17
11	10	200	6,988.00	2	3	19.35	7,007.35	694.57	13.62
14	10	200	6,988.00	2	3	19.35	7,007.35	510.30	10.81
16	10	200	6,988.00	2	3	19.35	7,007.35	680.40	17.30
18	10	93	2,920.20	1	2	12.90	2,366.02	.....	.....
21	10	93	2,920.20	1	2	12.90	2,366.02	751.27	42.80
25	10	88	2,353.12	...	....	.....	2,353.12	737.10	32.60
30	10	88	2,353.12	...	....	.....	2,353.12	722.92	25.60
June									
1	10	10	2,079.28	...	....	.....	2,079.28	.....	.....

TABLE XI. TIME AT WHICH OAT CULTURE AND OAT AND MUSTARD CULTURES ASSUMED THEIR MAXIMUM LEAF AREA, TRANSPIRATION AND RATE.

Designation of culture	Maximum leaf area		Maximum transpiration	Maximum rate
	Oats	Mustard		
Culture V Oats	April 20		May 21	May 25
Culture VI Oats and mustard	April 26	Feb. 16	May 30 Mustard eliminated April 13	May 25
Culture VII Oats	March 30		Feb. 6	Feb. 12
Culture VIII Oats and mustard	April 6	Feb. 9	March 19	May 21

the time of assumption of the greatest area. Then, too, there was a competition between the members of the same species. The data are given in table X.

Progress from time to time has been depicted in fig. 8.

The plan of summarizing the time at which the various cultures reached their maximum leaf area and maximum transpiration and maximum rate has also been followed for the oats series.

Again it is found that the culture without weeds, in this case, oats, made the maximum leaf area earlier than one which has mustard growing with it. For Culture VI the mustard no doubt was eliminated too early to produce the effect as shown in Culture VIII. The maximum rate was about the same thruout.

In the oats series there was no doubt but that 10 plants to a culture were too many and that there was not sufficient room for the production of plants having the best development. Competition between members of the same species has been as keen here as in the wheat series. It is plain that in Culture VIII where there were four mustard plants they were not able to compete in any sense with the oats. In this connection the height of the oats plants, the total dry weight, and the water used during the growing season were secured. The data are given in Table XII.

TABLE XII. HEIGHT DRY WEIGHT AND WATER TRANSPIRED DURING GROWING SEASON FOR THE OATS SERIES.

Designation of culture	Maximum height (cm.)		Dry weight of oats	Water used (Transpiration for season in kilograms)
	Oats	Mustard		
Culture V Oats	80	..	117.95	47.58
Culture VI Oats and mustard	73	7	112.30	48.55
Culture VII Oats	62	..	60.30	31.71
Culture VIII Oats and mustard	68	15	52.38	28.34

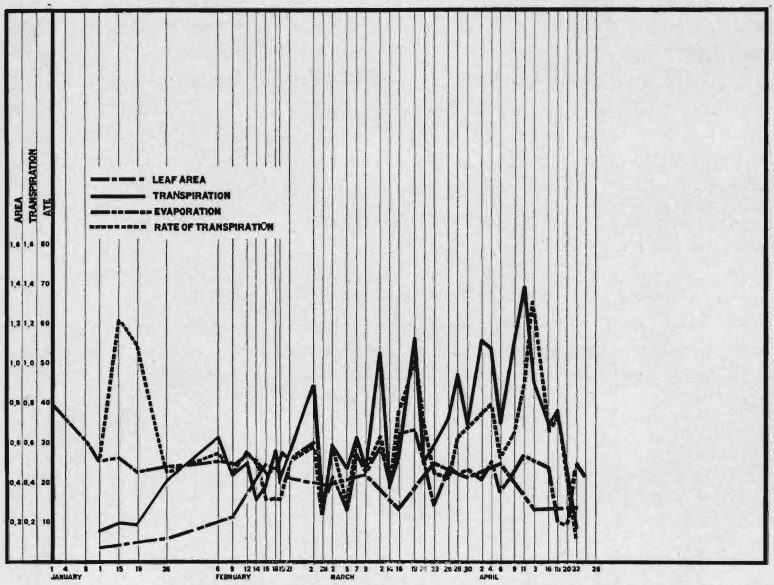

Fig. 9, culture IX, mustard. Leaf area, transpiration, evaporation, and rate of transpiration thruout the growing period.

The logical conclusion arrived at from the summarized table was that the dry weight of the cultures containing the oats alone was greater than when mustard was associated with the oats. The total amount of water used was considerably greater for Culture VI than for Culture VII. However Culture VIII gave off less water than the corresponding culture which contained no mustard. But it is to be rememberd that there were in the first place too many plants. There was not an appreciable difference in height.

Comparing the summarized record of maximum height, dry weight and total water loss for wheat and oats it is apparent that wheat grew to be taller than the oats;—the mustard grown with the wheat was much taller. The dry weight of the pure cultures of wheat alone was greater than where oats alone were grown. The wheat used more water than did the oats. It would then seem that oats would be a better crop to exterminate such weeds as mustard.

Series III—Mustard

CULTURE IX—MUSTARD

In making comparisons between mustard and wheat as well as between mustard and oats, there should by all means be at least one culture given over to mustard alone. From the data

submitted in table XIII, where three plants were present thruout, and four for a short period, the number of leaves increased from 25 to a maximum of 57 and corresponding areas of 345.5 sq. cm. to 5,369 sq. cm. The maximum rate reached 68.4 grams per sq. meter of leaf surface per hr. (GM^2H). The plants were mature by April 6 and soon after April 22 all the leaves had dropped off. The data for mustard have been tabulated in table XIII. The course of development has been graphically represented in fig. IX.

TABLE XIII. CULTURE IX—MUSTARD.

Date	No. of plants	No. of leaves	Area Sq. Cm.	Water loss (grams)	Water loss GM^2H
Jan. 11	3	25	345.50	155.92	27.53
15	3	25	345.50	205.53	61.95
19	4	25	345.50	182.27	56.45
26	4	15	990.00	403.98	33.60
Feb. 6	4	15	990.00	765.45	29.82
9	4	20	2,392.00	439.42	22.62
12	4	20	2,392.00	531.54	30.58
14	4	20	2,392.00	297.67	25.98
16	4	27	5,319.00	382.72	15.00
18	4	27	5,319.00	616.59	16.10
19	3	27	5,319.00	403.98	15.80
21	3	26	4,421.04	574.09	27.09
26	3	26	4,421.04	928.44	29.15
28	3	26	4,421.04	283.50	13.36
Mar. 2	3	31	4,274.90	659.13	32.16
5	3	31	4,274.90	503.19	16.31
7	3	31	4,274.90	701.64	34.19
9	3	36	4,557.60	496.12	22.65
12	3	36	4,557.60	1,091.47	33.00
14	3	36	4,557.60	396.90	18.01
16	3	29	3,045.00	595.35	40.65
19	3	29	3,045.00	1,176.52	53.65
21	3	29	3,045.00	552.82	37.68
23	3	46	5,428.00	623.70	23.95
26	3	46	5,428.00	779.62	22.75
28	3	46	5,428.00	1,006.42	32.40
30	3	50	4,535.00	722.92	34.70
April 2	3	50	4,535.00	1,162.35	39.50
4	3	50	4,535.00	1,112.73	43.15
6	3	57	5,369.40	751.27	29.15
9	3	57	5,369.40	1,190.70	35.18
11	3	57	5,369.40	1,431.67	46.81
13	3	32	2,931.20	963.90	68.40
16	3	32	2,931.20	737.10	34.74
18	3	32	2,931.20	822.15	40.05
20	3	27	3,078.00	.....	.....
22	3	27	3,078.00	184.27	6.62

TABLE XIV. READINGS OF TEMPERATURE AND EVAPORATION FROM DEC. 29, 1917, TO JUNE 2, 1918.

Date	Temperature		Evaporation from standardized atmometer	
	Minimum	Maximum	Cc. per hr. (day)	Cc. per hr. (night)
Dec. 29	9.44	26.67	0.627	0.475
" 30	13.89	22.78	0.620	0.472
" 31	15.00	26.11	1.290	0.390
Jan. 1	17.22	21.67	1.060	0.372
" 2	11.67	21.11	1.190	0.603
" 3	15.55	32.22	1.185	0.443
" 4	11.11	28.89	0.988	0.266
" 5	10.56	17.75	0.786	0.530
" 6	11.67	33.33	0.875	0.322
" 7	4.44	18.89	0.581	0.381
" 8	6.11	28.89	1.240	0.385
" 9	11.11	15.55	0.810	0.272
" 10	6.11	11.67	0.945	0.304
" 11	0.55	8.89	0.707	0.309
" 12	—1.11	13.89	0.972	0.322
" 13	4.44	10.55	0.536	0.353
" 14	5.55	36.67	0.796	0.421
" 15	13.89	38.89	0.717	0.504
" 16	15.00	28.33	0.470	0.498
" 17	12.22	25.00	0.620	0.408
" 18	12.22	28.33	0.536	0.516
" 19	13.33	26.67	0.482	0.476
" 20	14.44	33.89	0.680	0.435
" 21	17.78	25.55	0.786	0.322
" 22	8.89	28.33	0.611	0.390
" 23	11.11	20.55	0.461	0.504
" 24	10.55	29.44	0.649	0.494
" 25	10.00	21.11	0.476	0.321
" 26	11.11	22.22	0.514	0.690
" 27	10.00	25.55	0.544	0.335
" 28	10.00	12.78	0.340	0.494
" 29	10.55	23.33	0.457	0.486
" 30	5.55	30.00	0.476	0.340
" 31	2.78	17.22	0.574	0.821
Feb. 1	5.55	31.67	0.672	0.780
" 2	13.33	37.78	0.686	0.381
" 3	6.67	36.67	1.050	0.440
" 4	7.78	36.11	0.670	0.453
" 5	15.00	31.11	0.476	0.508
" 6	16.67	40.55	0.730	0.510
" 7	16.67	35.55	0.633	0.525
" 8	12.22	22.22	0.389	0.382
" 9	11.11	35.00	0.678	0.513
" 10	15.55	41.67	0.875	0.513
" 11	18.33	35.00	0.525	0.367
" 12	16.11	32.78	0.712	0.535
" 13	17.78	31.11	0.533	0.420
" 14	11.11	33.89	0.533	0.656
" 15	11.67	29.44	0.438	0.405
" 16	15.55	35.55	0.598	0.399
" 17	10.00	38.33	0.615	0.517
" 18	18.83	40.00	0.396	0.544
" 19	18.89	46.67	0.418	0.524
" 20	16.11	38.33	0.468	0.638
" 21	17.78	36.67	0.604	0.690
" 22	23.33	38.89	0.601	0.415
" 23	25.00	36.11	0.735	0.461
" 24	25.55	39.44	0.850	0.651
" 25	6.11	35.00	0.653	0.860
" 26	15.55	31.67	0.477	0.330
" 27	7.22	17.78	0.255	0.313
" 28	7.78	25.00	0.340	0.258
March 1	11.11	38.33	0.620	0.278
" 2	20.00	42.78	0.776	0.288
" 3	18.33	41.67	0.747	0.140
" 4	15.55	28.89	0.127	0.122
" 5	10.00	19.44	0.156	0.476
" 6	17.22	34.44	0.671	0.570
" 7	16.11	31.67	0.810	0.400
" 8	18.33	31.11	0.706	0.391
" 9	14.44	20.55	0.210	0.610
" 10	18.89	36.11	0.630	0.417
" 11	20.00	35.55	0.603	0.453
" 12	21.11	35.00	0.825	0.389
" 13	17.78	23.33	0.317	0.387
" 14	15.55	36.67	0.580	0.443

TABLE XIV. READINGS OF TEMPERATURE AND EVAPORATION FROM DEC. 29, 1917, TO JUNE 2, 1918—(Continued)

Date	Temperature		Evaporation from standardized atmometer	
	Maximum	Minimum	Cc. per hr. (day)	Cc. per hr. (night)
" 15	4.44	41.11	0.803	0.843
" 16	2.78	27.78	0.790	0.397
" 17	16.67	36.67	1.003	0.132
" 18	6.67	34.44	1.651	0.157
" 19	8.33	35.55	1.172	0.151
" 20	10.00	37.22	1.145	0.202
" 21	10.00	34.44	0.667	0.202
" 22	5.55	33.89	0.462	0.110
" 23	2.22	31.67	0.604	0.095
" 24	2.78	37.78	0.749	0.127
" 25	16.67	32.22	1.225	0.214
" 26	7.78	31.11	0.701	0.124
" 27	4.44	30.00	0.860	0.139
" 28	5.55	32.22	0.821	0.118
" 29	7.22	36.67	0.643	0.136
" 30	10.00	32.78	1.010	0.215
" 31	7.78	32.32	0.836	0.149
April 1	5.55	40.00	0.796	0.221
" 2	8.89	28.33	0.391	0.252
" 3	11.67	29.44	0.700	0.317
" 4	10.00	35.55	0.783	0.383
" 5	15.55	25.55	0.876	0.109
" 6	12.22	28.89	0.279	0.255
" 7	1.11	25.55	0.736	0.193
" 8	—0.55	35.00	0.616	0.311
" 9	14.44	27.78	0.726	0.377
" 10	17.22	28.89	0.770	0.362
" 11	16.67	31.11	0.786	0.394
" 12	18.89	32.33	0.719	0.304
" 13	17.78	30.00	0.816	0.408
" 14	20.55	28.89	1.220	0.379
" 15	20.00	24.44	0.378	0.168
" 16	17.78	30.00	0.780	0.232
" 17	11.11	26.67	0.250	0.313
" 18	10.55	32.78	0.016	0.299
" 19	17.22	21.67	0.272	0.186
" 20	8.33	14.44	0.223	0.141
" 21	7.78	31.67	0.423	0.569
" 22	13.33	25.55	0.795	0.385
" 23	10.55	36.11	0.665	0.143
" 24	16.11	32.22	0.648	0.403
" 25	14.44	37.78	0.809	0.141
" 26	16.11	41.11	0.567	0.236
" 27	20.00	43.89	0.657	0.185
" 28	17.78	38.89	0.386	0.210
" 29	19.44	31.67	0.292	0.219
" 30	7.78	35.00	0.740	0.463
May 1	5.55	31.11	1.480	0.326
" 2	11.11	32.78	1.440	0.362
" 3	10.55	31.67	2.534	0.463
" 4	14.44	31.11	1.765	0.544
" 5	10.00	23.33	1.755	0.341
" 6	14.44	33.33	0.264	0.147
" 7	14.44	38.89	0.992	0.304
" 8	15.55	40.00	1.650	0.295
" 9	10.00	38.33	1.134	0.281
" 10	7.78	31.67	0.082	0.123
" 11	9.44	32.78	0.894	0.236
" 12	6.11	27.22	0.755	0.308
" 13	5.55	36.11	0.774	0.363
" 14	18.89	36.67	1.935	0.408
" 15	18.33	40.00	2.380	0.648
" 16	18.33	39.44	1.960	0.454
" 17	18.33	37.78	0.454	0.463
" 18	17.78	33.89	0.704	0.245
" 19	15.55	40.00	0.940	0.219
" 20	11.11	33.89	0.973	0.326
" 21	16.67	32.78	0.242	0.136
" 22	12.22	33.89	0.536	0.209
" 23	8.89	27.78	0.825	0.031
" 24	16.67	37.22	0.680	0.168
" 25	21.11	38.44	0.892	0.254

TABLE XIV—(Continued)

May	26	20.00	33.33	0.468	0.090
"	27	17.78	33.89	0.257	0.050
"	28	20.00	36.67	0.673	0.680
"	29	20.55	35.55	0.295	0.100
"	30	22.22	39.44	0.675	0.290
"	31	21.11	37.78	1.070	0.200
June	1	17.22	41.11	0.950	.....
"	2	16.67	43.89	.....	.....

For the growing season the mustard culture gave off 23.321 kilograms of water and the plants were 35 cm. in height. Knowing that the most vigorous culture of wheat gave off 53.3 kilograms of water, the amount dissipated by such a weed is all the more pronounced, especially when it is remembered that there were 7 wheat plants as compared with 3 mustard plants.

Series IV—SOIL

Thruout the present study evaporation from the soil has been neglected. Naturally the greatest effect would take place during the seedling stage. However, the entire surface in a short time was covered with vegetation, so consequently soil evaporation was left out of consideration. It was recognized that there would be some error in doing this; but there would no doubt be limitation on growth if a plasticine covering were applied as soon as the plants had appeared above the soil. Even under such circumstances it was thought desirable to ascertain the amount of evaporation taking place. The water content of the soils series at the beginning was the same as that of cultures previously described. Weighings were made of the soil series at the same time as the others. The amount of water lost by evaporation was added at the time of the next weighing. Altogether there were given off 5.5 kilograms of water.

Daily during the period from December 29 to June 2 readings were made of the minimum and maximum temperatures as well as of the evaporation (by means of a standardized cylindrical form of atmometer). Evaporation readings were made in the morning as well as in the evening. These records are given in table XIV.

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